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AGROTECHNOLOGY

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RESISTANCE OF WHEAT TO ENZYMOMYCOTIC DETERIORATION OF GRAIN

Moscow VESTNIK SEL'SKOKHOZYAYSTVENNOY NAUKI in Russian No 4, 1978 pp 28-39

[Article by VASKhNIL Academician M. S. Dunin and S. K. Temirbekova]

> [Text] The personal socialist pledge of VASKhNIL Academician Mikhail Semenovich Dunin--a prominent scientist whose name is associated with the origin and development of Soviet phytopathology--was published in Issue No 1, 1977 of this journal.
>
> We can see from the article published below that M. S. Dunin and his colleagues are conducting deep research aimed at controlling grain losses associated with enzymo-mycotic deterioration. The results of their scientific work do not just have great theoretical significance alone; they also permit important practical conclusions. In particular, the authors recommend concrete methods for determining resistance of wheat to this disease.

The effectiveness with which cereal crops are protected against disease is one of the principal elements in the complex of measures spelled out by decisions of the 25th CPSU Congress in relation to completing the basic tasks of agriculture--increasing the gross harvests, improving grain quality, and heightening the stability of grain farming. The CPSU Central Committee and USSR Council of Ministers decree "On Measures for Heightening the Effectiveness of Agricultural Science and Strengthening Its Ties With Production" also points to the need for continued development of plant proctection systems and for a broad search for new, effective and safe plant protection methods, biological in particular.

Among the most important objects of research in this area, enzymatic (mainly carbohydrate-protein) deterioration, or so-called bleeding of the grain of wheat, rye, and other cereal crops, an almost universally occurring and, despite its great harmfulness, still poorly studied disease, occupies a special place. Losses caused by this disease during grain maturation and harvesting often attain 30 percent, in some cases exceeding half of

the expected biological yeild (Krasnodarskiy Kray, Siberia, the nonchernozem zone, the Ukraine, and many foreign countries). Moreover the commercial, flour milling, bread baking, feed, and sowing qualities of the grain worsen in the surviving part of the yield.

Our research, which we conducted at the Moscow branch of the VIR [All-Union Scientific Research Institute of Plant Growing] jointly with graduate students E. I. Buryakova from the Ryazan' Agricultural Institute and G. V. Kan from the All-Union Institute of Grain and Allied Products, and with Timiryazev Agricultural Academy students M. A. Gludman, A. S. Yeremko, and others, revealed in general terms the complex biological mechanism causing the arisal, development, and spread of this disease.

The etiology (abiotic causes and agents) and the principal features of the pathogenesis (arisal and development) of carbohydrate-protein deterioration of grain can be characterized as combined pathological processes proceeding in most cases in two stages, and sometimes with an additional qualitatively different, third stage.

I--The noninfectious stage of the disease: This stage can arise during any phase of grain maturation--at the time of milky, waxy, and complete ripeness. This stage arises and develops due to a significant and, in many cases, a dramatic increase in the activity of enzymatic hydrolytic processes in grain (by 150-500 percent and more over the normal level) and intensification of grain respiration not only during maturation but also to a certain extent after complete ripeness sets in, prior to and during harvesting time when the crops become moistened by rain or by intense dew and fog persisting for a long time, and in irrigated agriculture in response to late heavy irrigation when ears and grain hold higher amounts of moisture for a long time (40 hours for example). In such conditions, a highly significant proportion (15-30 percent and more) of carbohydrates--mainly starch, proteins, and some other photosynthetic products accumulating in the maturing grain often undergo deterioration as a result of enzymatic hydrolysis. Water-soluble, osmotically active compounds (sugar, protein decomposition products) forming in response increase influx of water into the grain from its moist surface, and thus they intensify further hydrolytic disintegration of reserve nutrients. Hydrostatic tensile pressure on cell walls in the caryopsis increases concurrently. When these processes develop intensively, some of the water-soluble hydrolysis products issue forth (are pressed out) from the grain through microscopic and, on occasion, breaks in the cell walls of the seed coat and the pericarp visible to the unaided eye, and through natural pores, as a result of which one can sometimes even taste sweet honeydew, or "manna" on the ears and grains. However, "honeydew" is unnoticeable or barely noticeable in most cases when hydrolysis of reserve nutrients in the grain is moderate.

In addition to hydrolysis, significant intensification also occurs in respiration--"cold combustion" of hydrolysis products in embryonic tissues and in the endosperm of the moistened caryopsis. Carbon dioxide forms as a result and escapes, and water liberated through respiration and remaining in part in the caryopsis promotes even greater intensification of hydrolytic and oxidative processes. Over a period of several dozen hours, especially in warm weather, these "chain reactions" can lead to large losses of grain dry matter and worsen the quality of the surviving part of the yield.

In most cases such "cold combustion" of water-soluble grain compounds formed through enzymatic hydrolysis (sugars for the most part) leads to losses of dry matter significantly exceeding those caused by just hydrolysis and "bleeding" of its products through the surface of the caryopsis, the hull, and so on.

The intensity of these processes varies significantly depending on weather, the specific features of the variety and species, the nutrition conditions, and the maturation phase of cereal crops. Quite often the increase in activity of amylase and protease and the greater intensity of seed respiration in response to rain and relatively high air temperature (for example at 25-30°C) are superseded by a decline in hydrolysis and respiration with the onset of dry weather and drying of the ears and grain. In this case photosynthesis can partially or, on rarer occasion, completely compensate for the losses of dry matter in the grain that had occurred previously, after which another period of moisture can cause a new wave of losses.

II--The infectious stage of the disease. It would be wrong to interpret the etiology and pathogenesis of this disease only as a consequence of a pathological increase in activity of grain enzymes. Semiparasitic and saprophytic fungi and bacteria, mainly of the genera *Alternaria*, *Helminthosporium*, *Cladosporium*, and *Fusarium*, participate intensively in its development.

Always in large numbers in the air, their spores colonize the seed coats containing hydrolysis products, germinate, and form a mycelium that penetrates into these coats and the grain. In this case fungi, and in part, bacteria produce and excrete enzymes intensifying hydrolytic and oxidative decomposition of organic matter.

All of this causes an even greater loss of yield and worsens grain quality. The longer and the more ear and grain moisture persists during maturation and harvesting, the more significant is the economic loss due to caryopsis deterioration.

The danger in lodging of wheat and other cereal crops becomes more understandable in this connection. As compared to erect ears or ones partially bent over on erect stems, the ears of such cereal grains retain excessive moisture several times longer following rain, abundant dew, or fog.

Given particular conditions in terms of the moisture content and temperature of ears and grains and the composition of nutrient hydrolysis products, some species and strains of fungi in infected plant tissues accumulate toxins reducing sprouting energy and seed germination. In some cases certain strains of fungi produce toxins damaging the mucous membranes, digestive system, and nervous system of homeothermic animals and man eating such grain or the products of its processing. Such intoxications include "drunken bread" (a special form of grain fusariosis) "septic angina" and alimentary-toxic aleukia, and various forms of aflatoxicosis.

Diseases of wheat ears and grain called "black point disease," kernel smudge, "mykhosed," or moucheture have been described in the USA and a number of other countries. Typically, foreign researchers believe fungi in genus *Alternaria* to be the main cause of these diseases, which cause tremendous losses (up to 30 percent of the grain yield). But as follows from the above, presence of such fungi on ears and kernels and in their internal tissues means that these saprophytic and semiparasitic fungi are not at all the sole and principal cause of such losses, being instead the second stage of enzymomycotic grain deterioration described above.

These stages set in not only because of significant moistening of kernels and grain but also, as a rule, because the nutrient medium formed as a result of hydrolytic enzymatic breakdown of grain carbohydrates and proteins is close to optimum for fungi.

We learned from our observations and experiments that similar factors often go along way in promoting arisal and development of other diseases such as septoria spot of wheat ears, white rust of corn ears, alternariosis of the pods and seeds of Cruciferae (seed cabbage, stock, and so on) and, in some years, catastrophically harmful gray rot (botrytiosis) and white rot (sclerotiniosis) of sunflower heads and seeds.

It also follows from the data above that the terms "bleeding" or "leaking" of grain and "black mold" on grain, in common usage in domestic agricultural literature and practice, are incorrect. They characterize only part of the etiology and pathogenesis, moreover the lesser part of the yield loss caused by enzymatic hydrolytic or mycological factors. To make matters worse, these terms often create an incorrect impression among even some specialists that the kernels themselves are discharged or leaked out from the ear and that they undergo shattering when harvesting is late.

The name we suggest for this disease, enzymomycotic grain deterioration, describes the main features of its etiology and pathogenesis more fully and correctly.

The third stage of the disease: On the background of the two stages of grain deterioration described above, a qualitatively different stage arises

on occasion--sprouting of the grain in ears while still rooted, in windrows, and sometimes even in moist heaps. The incidence and harmfulness of this phenomenon are limited mainly by the three following factors.

The so-called period of physiological rest, which is even typical of the mature seeds of many wheat varieties is a unique inhibitor of grain sprouting during the time of its maturation and harvesting. A clearly expressed lengthy period of physiological rest of seeds as a rule fully precludes or considerably restricts the danger of wheat grain sprouting prior to or during the harvest even in the presence of persisting rainy weather.

Another factor preventing seed sprouting even after the period of physiological rest is that their moisture content is below a certain minimum, different for each species of plants. This is why even varieties of seeds that do not undergo a period of physiological rest do not sprout when moisture content is insufficiently high.

Seed temperature is the third factor limiting the possibility of seed sprouting. This is why seeds either do not sprout or sprout to a limited extent even in the presence of excessive moisture persisting for a long period of time in the pre-harvesting period and in windrows in the north-eastern zones of the USSR when air temperatures are low (9-5°C), assuming separate harvesting of the seeds.

Thus together with the noninfectious and infectious pathological processes typical of the first two stages of enzymomycotic grain deterioration, the third qualitatively different stage can arise only if the particular variety does not undergo a period of physiological rest or if it experiences the other mentioned conditions.

Interaction of these three factors is what causes the relatively very rare (and, moreover, in the smaller proportion of zones and regions) sprouting of kernels in ears while the plant is rooted and in windrows, as well as in moist heaps during harvesting, in comparison with the universal occurrence of the first two phases of grain deterioration.

Disease Symptoms and Diagnosis

The Milky Ripeness Phase

1.1. The symptomless (incubational) period of the disease in response to moistening of the ears and kernels by rain, dew, or fog.

1.1.1. Enzymatic hydrolysis of grain starch and proteins and their subsequent decomposition (oxidation) in the absence of visible symptoms. These pathological processes can be used to diagnose the disease and describe its dynamics quantitatively:

1.1.2.1. On the basis of accelerated respiration of moistened grain, in comparison with an intact control.

1.1.2.2. On the basis of the loss of dry matter (the simplest index would be decline in weight of dry matter per 1,000 kernels).

1.2. The symptoms:

1.2.1. When the affliction is severe: Appearance of a sweet or slightly sweet exudate--"honeydew" or "manna"--on ears and kernels due to carbohydrate hydrolysis and the resulting increase in osmotic and hydrostatic pressure in caryopsis cells.

Note: This diagnostically valuable symptom is outwardly similar to "honeydew" on rye ears infected by ergot, but it is distinctly different in that single-celled colorless spores typical of the latter are absent. Moreover ergot infection is encountered in wheat only in sporadic cases as a rule, in contrast to the almost universal occurrence of enzymomycotic grain deterioration.

1.2.2. The microsymptom: Disturbance of the structural integrity of starch granules and "chewed" edges on the granules as a result of enzymatic hydrolysis. Microscopic study of samples reveals stricken kernels.

1.2.3. When disease development is intense, first small, usually longitudinal cracks, barely visible to the unaided eye, appear on the kernel hull, which later become more obvious; this is sometimes accompanied by change in kernel shape--swelling and softening in response to higher hydrostatic pressure mainly in cells of the endosperm.

Note: This sympton of wheat kernels is similar to rupture of kernel hulls in corn infected by "white rust" accompanied by development of fusariosis, and to ruptures (splits) in the upper half of the heads of plants in family Cruciferae in response to the intitial effects of moist, warm weather and heightened hydrolytic activity of enzymes.

1.2.4. Colonization of hulls and the surface and internal parts of kernels by *Alternaria*, *Helminthosporium*, *Cladosporium*, *Fusarium*, and in some cases, toxic strains of *Stachybotrys alternans*. In the absence of outward symptoms, colonization of kernel hulls and surfaces and infection of internal kernel tissues by these fungi can be revealed through mycological analysis of samples in a moist chamber at 25-28°C for 40-60 hours.

The Waxy Ripeness Phase

As in the milky ripeness phase, the disease does not arise in dry weather, but it can be initiated by the onset of moist weather (rain, long-persisting dew and fog). In these conditions the pathogenesis of the disease is accompanied by symptoms 1.1.-1.2.4, with the exception of 1.2.3.

2.1. A mycelium-spore deposit having the appearance of black spots; isolated or merging black spots of varying shape and dimensions on kernel hulls and on the caryopsis surface ("fungus black" or "black mold").

The Complete Ripeness Phase

In relatively rarer cases the disease may begin in moist, warm weather and develop quickly following the onset of complete ripeness of wheat, before and during harvesting, and in heaps of thrashed moist grain. In these conditions the symptomless phenomena (1.1.1-1.1.2.2) are accompanied by "milder" symptoms (1.2.1 and 1.2.2), a distinctly pronounced external symptom 1.2.4, and internal infection of the kernel and ear hulls.

3.1. Blackening of the grain embryo.

3.2. Decline in grain vitreousness. Arisal of yellow spots that can be seen through the seed coat (owing to focal hydrolysis of starch in the endosperm).

3.3. Puniness of air-dried grain due to exhaustion of its nutrient reserves.

Note: This symptom is nonspecific to enzymomycotic grain deterioration, but it nevertheless does have extremely important diagnostic significance when considered in integration with the conditions under which the wheat matures, rather than separately. In this case puny grain differs dramatically from that seen following "thirsty wind scorching" of grain, since rather than being caused by a lack of moisture in air and soil in combination with the effect of thirsty winds, it develops in the presence of sufficient and even excessive moisture in air and soil during maturation and (or) harvesting of the yield.

Puny grain is encountered extensively also as a consequence of infection by various species of root rot. But this type of disease can be diagnosed without special difficulty on the basis of specific morphological and other characteristics of the agents. Also just as specific are the diagnostic features and puniness of grain caused by some pests such as greenbugs, thrips, chinch bugs, and helminthic "kernels" (galls). Moreover in most cases it is caused by the interaction of two or several factors, and not just some one alone.

3.4. Sprouting of kernels in ears on rooted plants, in windrows, and in heaps of thrashed moist grain.

3.5. Self-warming of grain having a heightened (nongrade) moisture content in heaps and granaries, and in response to the effect of "foci" taking the form of moist (immature) seeds of this cereal crop and weeds. These processes are a unique continuation and modification of pathological activation of hydrolytic and oxidative enzymes caused by the first two stages of grain deterioration.

3.6. Intoxication of grain due to its colonization by toxigenic species and strains, mainly *Fusarium*, *Aspergillus*, *Stachybotrys*, *Alternaria*, and some other fungi. Toxicological tests can be employed to diagnose such grain (and chaff) (feeding it to experimental animals, the "eye test" on rabbits to reveal toxins having inflamatory and abscess-forming action, testing the effect of toxins on seed sowing qualities and so on).

Methods for Assessing Resistance of Wheat Varieties to Carbohydrate-Protein Deterioration of Grain

Among the protective measures,* use of varieties in which the needed economically valuable traits and properties are combined with resistance to enzymomycotic grain deterioration during maturation and harvesting of the wheat should occupy one of the main places.

Research I conducted together with Ye. I. Buryakova (Ryazan' Agricultural Institute) established that samples of varieties in the VIR collection and wheat varieties regionalized for Ryazanskaya and Moscow oblasts vary significantly in resistance to this disease. Thus in 1966 and 1977 the loss of yield on fields of the Moscow branch of the VIR caused by enzymomycotic grain deterioration varied within 15-48 percent for Mironovskaya 808, Bezostaya 1, Polesskaya 70, and within 3-12 percent for Moskovskaya 35, Odesskaya 51, Ibis, Feliks, and Karibo.

A similar law was also noted for occurrence of fungi in these varieties. It was 40-100 percent for the first group while for the Ibis variety, one of the varieties in the second group most resistant to grain deterioration, this index did not exceed 1 percent, with almost total absence of powdery mildew and with mild infection by brown rust, which affected varieties in the first group to a moderate or intense degree. These and other facts persuasively attest to real possibilities for creating new, highly productive wheat varieties resistant to enzymomycotic grain deterioration.

Emphasizing the priority significance of varieties resistant to lodging and associated grain deterioration and the dramatic decline in yields, twice-awarded Hero of Socialist Labor Distinguished VASKhNIL Academician T. S. Mal'tsev appealed fervently that we spare no effort to create such varieties, pointing out that such efforts would be compensated a hundredfold.

M. L. Kravchenko, a breeder of the All-Union Institute of Genetics and Selection Rovno Research Station, also emphasizes the leading role of directed selection in solution of this problem. In his opinion grain "discharge" in this zone is the main cause of lower wheat yields.

During moist weather at the time of wheat maturation and harvesting in 1975 and 1976 in Ternopol'skaya Oblast (Ukrainian SSR) and in the

*Presentation of these measures is the object of a separate communication.

Moldavian SSR, the yields of strains resistant to grain deterioration--Ibis, Karibo, and the variety created by M. L. Kravchenko, Mil'turum 1 (a *Triticum oestivum* × *Triticum durum* hybrid) exceeded the yield of standard varieties by 4-14 c/ha (the yield being about 60 c/ha).

In addition to the examples cited above, general considerations also point to the need for all-out development of the selection of wheat for resistance to enzymomycotic grain deterioration in all of the listed zones, where in view of climatic conditions it is subjected especially often to the intense effects of excessively moist weather during maturation and harvesting time.

Sensible selection of the raw material has decisive significance to the success of selection in this direction. The role of effective and practically applicable methods for assessing resistance of the initial forms, intermediate selection products, and new varieties to this disease is important as well.

Indirect signs of resistance: In the first approximation and with the purpose of checking varietal differences, it would be suitable to use indirect signs of resistance such fast ripening, firm ears, tightly fitting seed coats; waxy ("hydrophobic") deposit on leaves, stems, and ear hulls; tilting (flexture) of ears containing swelling grain, promoting drainage of rainwater; absence or moderate development of awns, limiting accumulation and retention of rainwater and dew in the ear; presence of a clearly pronounced period of physiological rest (not less than 2 weeks) following the waxy ripeness phase.

Absence of the signs of "honeydew" in wheat ears even following lengthy rains and warm weather is important during maturation and harvesting time.

Absence or a small quantity (not more than 10 percent) of puny kernels and weakly pronounced puniness, exhibited mainly on the groove side, following rainy weather and intense dew and fog is important.

Resistance to lodging: Kernels in ears on rooted plants and in windrows subjected to prolonged moistening by rain in warm weather must be resistant to sprouting.

Amylase activity in grain in response to rain and intense dew and fog must be lower than that of regionalized varieties in the appropriate phases. Starch breakdown by amylase, which can be revealed biochemically and by micromorphological detection of damaged starch granule structure, must be lower than that of regionalized varieties.

Kernels with "mealy spots" (a symptom of significant starch hydrolysis) visible through the hulls of undamaged kernels must be absent, or present in small quantities (not more than 10 percent).

Semiparasitic and saprophytic fungi ("black mold" or a pinkish-orange fusariotic color) should be absent from hulls, stems, and kernels, or poorly developed, as assessed on a five-point scale.

Presence of fungi on ears and kernels is scored with the following points: 0--Absence of "black mold" and (or) fusariosis; 1--mild development of the latter in the form of a few black spots or pinkish-orange fusariotic spots; 2--moderately intense development of "black mold" in the form of small isolated black or pinkish-orange fusariotic spots taking up not more than a third of the surface of ear and (or) grain coats; 3--intense development of the same symptoms in the form of merging spots occupying up to two-thirds of the surface of hulls and (or) kernels; 4--very intense development of the same symptoms in the form of for the most part interconnected spots taking up more than two-thirds of the surface of hulls and (or) kernels.

The possibilities for direct comparative assessment of resistance of wheat varieties and species to deterioration of maturing grain have now been defined in the first approximation.

The following basic premises are at the basis of the methods we studied.

Obvious dominance of the harmful action of water droplets on ears and kernels rather than on leaves or stems. Thus when water droplets fell only on leaves and stems the yield loss was 4.7 percent, while when they fell only on ears and kernels it was 66 percent (N. G. Kholodnyy, 1949).

Differences in sensitivity to carbohydrate-protein deterioration of kernels in different phases of maturation. At the time of milky ripeness the caryopsis is most sensitive to the action of factors eliciting the first stage of disease, it is less sensitive during waxy ripeness, and even less sensitive at the time of complete ripeness. Thus when we perform initial analyses on a major scale, it would be suitable to comparatively assess samples in the milky ripeness phase and, as a control, in the waxy and complete ripeness phases.

Synchronous and synphasal sampling and sample analysis. When ripening rate is the same, the samples should be taken simultaneously in the appropriate maturation phase. However, with varieties different in ripening rate, we must follow the principle of synphasal sampling: The samples should be taken and analyzed at different calendar times but during the same phases of grain maturation, initially determined by the commonly accepted organoleptic techniques. In this case, we should account for the certain difficulties and the possible sources of subjective errors in determining the synchronous and (or) synphasal times to take the samples for analysis. We can reduce the frequency of such errors by taking, as our conditional, objective quantitative criteria, indices such as the time of mass flowering of standard varieties and ear and kerneal moisture content at midday in clear weather. However, these and other possible reference points must be subjected to further testing and stricter definition so that the methods could be improved.

A control (intact) sample of ears containing kernels not subjected to the experimental moistening conditions is a mandatory standard of each variety.

Fourfold (or, as a minimum, threefold) replication of analysis of each sample or of other variants of the experiment.

The elements and methods of accounting for resistance to grain deterioration: Dry matter loss in experimental samples ($L_{\%}$), expressed as a percent in relation to dry matter content in control (intact) samples,* is defined as the principal (direct) index of resistance of the wheat variety to enzymomycotic grain deterioration during its maturation and harvesting.

If necessary, for example when assessing the most promising variety samples, we can use commonly accepted methods to determine moisture content, dry weight, and other indices such as volume-weight, vitreousness, color, starch, protein, and sugar content, enzymatic activity, incidence of different species of fungi in ears and kernels, and so on. When an amylograph, a (Khaberg-Perten) apparatus and other apparatus of similar purpose, and the appropriate reagents (for example standard starch preparations) are available, it would be suitable to make direct comparative determinations of alpha-amylase activity and the so-called decrease number. Microscopic and biochemical methods for determining breakdown of starch granules by enzymes in experimental grain samples can also be important.

In addition to the elements and methods of accounting for resistance mentioned above, we can also describe variety samples by the frequency of occurrence of various fungi on ears and kernels. Even an organoleptic assessment based on these indices can provide valuable information on the relative resistance of the varieties under analysis.

Given their great value, none of the methods listed above can be readily applied due the high cost of the apparatus, the great effort required, and the cumbersomeness of the equipment; others require use of reagents that are hard to get, and still others (pathomorphological assessment of the degree of damage to starch granules by enzymes) require deeper definition.

This is why to determine resistance of wheat, barley, and triticale we primarily studied the possibility for using natural rain, various sprinkling methods, and other ways for modeling the hydrothermal regime (for example, using a portable field chamber to moisten small groups of ears).

*Depending on the specific features, goals, and tasks of the research, other ways for expressing loss are possible, for example in relation to the corresponding loss suffered by a standard variety, or in relation to the dry matter yield of the intact variant.

At the present stage of work on this aspect of the problem, we can use the following standard schemes and their modifications in application to different tasks and conditions for determining resistance of varieties and species of these cereal crops.

1. Assessment of samples exposed to natural rain: Eight samples with five typical ears in each are predesignated in different places on an experimental plot of wheat at the start of its milky ripeness phase; without separating the ears from the plants, they are tied loosely together. Four control samples (replications C_1 and C_4 and as many experimental samples E_1 and E_4), are isolated and supplied with the appropriate tags.

Next, following short-term weather predicitions and personal observations, not long before a rain the four samples in the control group, C_1-C_4, are covered with polyethylene or other waterproof hoods (20×30 cm). After the rain the hoods are removed and placed over ear bundles in the second (experimental) group, E_1-E_4. The goal of this operation is to keep the moisture content of rain-moistened ears in the experimental samples high for a sufficiently long period of time, a day and a half or two days for example.

Opaque white hoods should be used to prevent overheating of these samples in sunny weather.

When rainy weather persists for a long time, the control ear samples (C_1 and C_4) are kept beneath the hoods until the rain stops or until they are sampled for analysis.

In order to permit comparison and replication of testing conditions, daily changes in ambient air temperature and the temperature beneath the hood of one of the samples should be recorded.

Upon expiration of the planned experimental time all ears are cut from the control (C) and experimental (E) groups and delivered in waterproof bags to the laboratory together with the corresponding tags, each sample bundled separately. In the laboratory, the kernels are removed from all ears in each sample separately, kernel weight is computed, and average moisture content and dry weight are determined per 1,000 kernels in the control (C) and experimental (E) groups of samples.

The following formula is used to determine dry matter loss ($L_{\%}$), the index of variety resistance:

$$L_{\%}=\frac{(C-E)\cdot 100}{C}. \qquad (1)$$

Similarly, samples are prepared and dry matter loss ($L_{\%}$) is determined for kernels at waxy and complete ripeness.

2. Assessment of variety samples exposed to artificial sprinkling: When it becomes to necessary to comparatively assess varieties in dry weather during the time of wheat maturation, artificial sprinkling can be used on small plots (0.5-1.0 m^2).

The testing scheme is the same as for the first method: Prior to sprinkling, the bundles (samples) of control ears (group C) are covered with hoods which are removed after sprinkling. Then the experimental samples (group E) are covered with the hoods to prevent their rapid drying. For this purpose the lower edges of the hoods are drawn closed with a cord, without damage to the ears and their stems. Sprinkling is repeated three to five times for a day and a half or two days depending on daily weather changes during the day and at night.

Experimental plots are sprinkled with a backpack sprayer for about 4-5 minutes until the plants are completely wet--until droplets begin to drain from the ears.

Light, sufficiently strong frameworks covered with film, equal in area to the plots and exceeding the height of experimental plants by 40-50 cm, are used on whole plots for tests with natural rain or sprinkling. Not long before rainfall the "roof" of the framework and, when the control plots are small, the sides are covered with film, which is removed (parted) after the rain, and soil in the test part of the plot is uniformly irrigated without wetting the ears, in an amount corresponding to that of the previous precipitation or the quantity of water used to sprinkle the experimental plot (E). When sufficiently high ear moisture content must be maintained in group E plots, the latter are subjected to repeated short sprinklings for 1-2 days and more, while soil in control plots is irrigated by an amount of water equal to that used in sprinkling. The details of other technical and procedural standards are determined in application to local natural and farming conditions and the peculiarities of the test.

3. The separated ear method: This method permits us to reproduce, though to a lesser extent, the details of the irrigation conditions under which microenzymatic grain deterioration occurs in a natural situation during maturation and harvesting. At the same time this method has highly important advantages typical of it and not the other: High productivity, simplicity and availability of the laboratory equipment, and replicability of the various hydrothermal and other conditions being utilized or studied.

The sequence and the technical standards of the operations involved in this method boil down to the following.

At a certain time 40 typical ears in the milky ripeness phase are cut from plants of the variety under analysis in different places (it would be suitable to take the same sort of samples in the waxy and complete ripeness phases for control analyses). These ears are delivered to the laboratory in a waterproof bag and divided into two groups with four samples in each--control (not moistened) samples (C_1-C_4) and experimental samples (E_1-E_4).

All kernels are immediately removed from each sample in the first group and counted, and the average moisture content and dry matter weight (C) are determined per 1,000 kernels.

Ear samples in the second (experimental) group (E_1-E_4) are submerged in tap or distilled water, heated to 30°C, for 10 minutes.

After the 10-minute wetting the experimental samples are removed from the water, the excess is allowed to drain off for 3 minutes, and then the samples are laid down horizontally (to permit faster, more uniform redistribution of water in the ears and kernels) for 2 days in a moist chamber at 30°C with a relative humidity close to 95 percent.

Note: In some cases the samples (E_1-E_4) are resubmerged in water for 5 minutes and then replaced in the moist chamber in order to intensify hydrolysis and respiration.

Following 2 days in the moist chamber, all kernels are removed from the experimental samples and counted, and their average moisture content in each of the four samples and dry weight (E) per 1,000 kernels are determined. The dry matter loss ($L_{\%}$) and the indices of relative resistance of the variety samples to grain deterioration are determined using formula (1).

4. Quick initial assessment of dry matter loss in whole grain-filled ears. A simplified modification of the described methods (1-3) can be used in large-scale comparative determinations of dry matter loss elicited by enzymomycotic deterioration of cereal grains. It essentially entails determination of this loss in whole grain-filled ears without removing the kernels. While less accurate, such determination reduces labor outlays by many times and, at the same time, reveals quantitative differences in resistance of variety samples, and the influence of factors such as the method, degree, and time of moistening of ears and kernels, temperature, fertilizer, retardants, pesticides, and so on.

The field tests (indicated in the first and second methods) are performed in the following order in this modification. In accordance with the conventional standards of randomization, identical (for example 15-gram) samples are taken with a 0.1 gm accuracy from each of the samples of control (C_1-C_4) and experimental (E_1-E_4) ears. The dry matter content and the numerical value of formula (1) are determined first for each sample separately and then on the average for each group (C and E).

When the separated ear method is used to determine this index, four 15-gm ear samples are removed from the entire sample (C_1-C_4 and E_1-E_4). Immediately after their removal, the average dry matter content (C) is established for samples in the first group. Samples in the second group (E_1-E_4) are processed in accordance with the standards of this method (3), and in conclusion the numerical value of $L_{\%}$ is determined using formula (1).

Numerical values of $L_{\%}$ in tests differing in relation to time and other conditions can differ for the same sample or experimental variant depending on weather, the degree of moistening of the experimental samples, and the time they remain moistened. But when an experimental set of samples is tested simultaneously in the same place, this method permits us to make a quantitative assessment of the crop collection under analysis or variants of other experiments; the obtained average data are ordered in series of diminishing or increasing resistance (or susceptibility), similarly as is done when assessing collections of variety samples for resistance to rust, smut, and other diseases. This affords a possibility for revealing the donors of the resistance trait, evaluating intermediate products of selection and the selected material, and clarifying the effect of ecological, agrotechnical, chemical, and other factors on the dimensions and quality of yield loss due to enzymomycotic grain deterioration.

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ERGONOMICS AND LABOR PROTECTION

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> /Text/ "Our goal can be formulated as follows: from labor safety techniques to safe equipment."
>
> L. I. Brezhnev
> Speech at the 16th Congress of the
> USSR Trade Unions

The maximum possible improvement and facilitation of working conditions are important integral parts of the policy of the socialist state. The concern for improvement of working conditions is reflected in the new USSR Constitution. The right of Soviet citizens to health protection, along with an extensive system of other measures, is also ensured by the development and improvement of labor safety techniques and industrial hygiene.

To make new advances in this matter, it is necessary to more widely utilize the possibilities of scientific and technical progress. All technical sciences participate in one way or another in ensuring the safety of developed equipment for man. Their data are used during the development of protective measures, in labor safety techniques, industrial acoustics and lighting engineering, and during the design of individual protection devices, ventilation, dust elimination and air conditioning equipment and so forth.

Overall investigations conducted by means of methods of various scientific disciplines, whose combination is determined by the nature of the problem, have been developed extensively in the study of labor activity. Several trends in interdisciplinary investigations devoted to various applied problems of labor activity, such as scientific labor organization, labor protection (safety) and design, have now been formulated. In the design of equipment and the conditions of its functioning with due regard for the capabilities and characteristics of the working man (group of people) all of them are based on ergonomics.

The system of legislative acts and of the socioeconomic, technical, hygienic and organizational measures ensuring man's safety and preservation of his health and work fitness in the process of labor, measures corresponding to the above acts, forms the content of the concept of "labor protection."

Ergonomics is connected with labor protection in one of its trends--investigations and recommendations on problems of improvement and safety of working conditions. We shall attempt to define the connections and boundaries between ergonomics and labor protection.

Historically, ergonomics emerged as a synthesis of the studies in the field of sciences of man and in a number of technical sciences necessary to ensure his participation in modern production. The process of formation of ergonomics continues. The system approach in theoretical investigations and in the practical use of ergonomics now creates the prospects for its development as a special scientific discipline. The formation of ergonomics--a special scientific discipline--is connected with the fact that the "coordination of man's physical and psychic capabilities, esthetic tastes and other social qualities with the properties of modern technical systems, not equipment in itself and not only man as the subject of production, becomes the subject of scientific investigation in the field of labor activity" /11/.

The development of standards, requirements and recommendations used during the designing of technical facilities, machines and control systems, organization of work places and improvement in working conditions is the applied task of ergonomics. In this respect ergonomics, similarly to hygiene in medical sciences, represents a standard discipline.

Consideration of ergonomic requirements is the condition necessary for the development of convenient, reliable and safe equipment. This ensures an improvement in the efficiency and quality of labor, convenience of operation and servicing, improvement in working conditions, shortening of the time of mastering equipment, saving of the expenditures of the working man's physical and nervous-psychic energies and maintenance of his high work fitness. The degree of realization of the economic effect potentially inherent in equipment depends on the extent to which it corresponds to ergonomic requirements. Ergonomic support for the designing of equipment contributes to the attainment of certain social goals and results--increase in the attractiveness and meaningfulness of labor, preservation of health and creation of conditions favoring an all-around development of the working man.

Let us examine the main aspects of the connections between labor protection and ergonomics.

Ergonomics and dangerous production factors. In labor protection it is customary to call the factors that can lead to accidents on the job--to traumatic injuries in working people--dangerous. When analyzing accidents, it is necessary not only to take into consideration the multiplicity of their causes, but also to examine the entire situation that gave rise to an accident and how it developed in time /3; 16/.

It is customary to single out the technical and organizational causes of accidents. The former include nonobservance of the rules of execution of the technological process, failure of machinery and other equipment, defects in the design, manufacture or installation of the used equipment and so forth. Organizational causes include unsatisfactory instructions on safety requirements, a lack or nonuse of protective gear and so forth.

It is important to correctly evaluate the significance of the personal factor directly determining the occurrence of accidents or forming part of the set of their causes. The personal factor is defined as the combination of the physical and psychic characteristics of a personality that can be connected with an accident. Practice shows that the causes of accidents should be sought not only in man's individual characteristics (personal factor), but also in his insufficiently well-organized interaction with equipment (human factors) /4/.

I. Saari /5/ believes that the sphere of ergonomic analysis of the causes of possible accidents should include an investigation of the features of a work task as the first group of variables, of the characteristics of an individual, as the second, and of the dangers connected with the equipment of a work place, as the third. For example, an operator's error can depend on the specific combination of conditions in the "man-machine" system including interaction equipment, operational problems and methods and the physical and social environment. Therefore, it should be considered that an error is due to the man-machine system as a whole and does not depend on one operator alone. It happens that a danger is caused directly by an unsuccessful design solution of equipment. In most cases, however, an unsuccessful design stimulates the erroneous actions of the working man /16/.

The problem concerning the fact that the requirements for improvement and safety of working conditions should become integral organic parts of the process of development of equipment and not be attached to it externally, as something extraneous and independent, was raised in our country in the 1930's /10/. Under present conditions such a formulation of the problem has become a realistic task. The closest connections between labor protection and ergonomics making an important contribution to the elaboration of scientific and methodological problems of development of safe equipment are formed along the path of its solution. The principles and methods of development of safe equipment are most intensively worked out in the process of designing complex technical systems, airplanes, spaceships and other facilities. "In our opinion, an overall ergonomic approach based on a whole set of experimental studies conducted a long time before the first flight of an experimental airplane," believes general designer O. K. Antonov, "will make it possible to lay the foundation for a sharp rise in the indicators of flight safety and to shorten the time of flight tests and aircraft development" /1/.

F. Blanchard, director general of the International Labor Organization, described the capabilities of ergonomics in the solution of problems concerning the safety and improvement of the industrial environment as follows:

"First of all, by means of ergonomics it is possible to make corrections. In this case it establishes a contact between the physician in industry, who ascertains the unsuitability of a machine for a worker, and the engineer, who can correct this... However, ergonomics has many more capabilities if it is attached to the concept of the equipment itself" /2/.

In the future it can be expected that ergonomics will determine to an ever greater extent the content of the requirements for labor safety and, therefore, the scientific and practical work on labor protection. "Labor safety techniques," noted S. Filipkowski, a Polish specialist in the field of labor protection and ergonomics, "consisted in the use of equipment and methods eliminating danger, that is, in providing the safest working conditions with a given production technology and organization. In contrast, safe equipment presupposes an overall solution of the problems of labor safety at the stage of designing of industrial equipment. Such an approach differs from the foregoing one in its very essence" /13/. A machine designed without taking human factors into account can cause an error by the working man, which in turn can lead to an unsafe labor activity with this machine. In this connection problems arise and labor protection can solve them efficiently only in close cooperation with ergonomics, which is engaged in the study and optimization of the conditions and methods of man's activity in the man-machine system. "Since man's organic inclusion in the system is the basic function of the specialist in human factors, who is better prepared than he for a search of methods of eliminating unsafe actions?" notes the American specialist F. Cecich. "Utilizing widely recognized ergonomic principles, the specialist in human factors is in a key position to determine the hidden causes of unsafe actions that can lead to accidents" /12/.

It is quite natural that, along with an intensive development of work on standardization in the field of ergonomics, the requirements of this discipline are ever more widely included in labor safety standards. In turn, a strict observance of these standards is an obligatory condition for the execution of economic work aimed at improving equipment and working conditions. "In the future there will be a transition from the solution of urgent labor organization problems, improvement in existing equipment and man's adaptation for the already formed technological norms to the planning of new types of human activity on the basis of an overall theoretical investigation of man's potentials, in which ergonomics is already engaged" /11/.

Ergonomics and harmful production factors. In labor protection it is customary to call the factors whose effect can lead to diseases harmful. Of course, the differences between harmful and dangerous factors are conventional.

Harmful and dangerous production factors are divided into four groups according to the nature of their effect--physical, chemical, biological and psychophysiological factors. The first three groups include the effects of the environment and industrial equipment. For example, they include noise and vibration, various radiations, dusty air and air contaminated with gas and infected with microorganisms and so forth. The fourth group--psychophysiological

factors--characterizes the change in man's state under the effect of hard and strenuous labor. In principle, the effect of all the factors is similar, because, as a result, excessive work loads can also lead to diseases.

The recommendations aimed at preventing or reducing the effect of harmful factors include the establishment of the maximum permissible levels or maximum permissible concentrations for each of them. In our country these levels or concentrations are calculated so that, when they are observed, any harmful effect may be eliminated. They are determined so that they may be not only lower than the average values, but than the entire range of values of the threshold of the harmful effect of a certain factor.

Ergonomics follows the recommendations for the prevention and reduction of the harmful effect of physical, chemical and biological factors, which are the subject of studies of the science of hygiene. The standardization of psychophysiological harmful factors, that is, excessive work loads, is not yet developed efficiently. Ergonomics is to play a very crucial role here. Whereas labor hygiene is engaged mainly in the study of the features and patterns of the interrelationship of factors forming the component of the environment system, ergonomics pays principal attention to the study of the relationships between these and other components of the man-machine-environment system and the direct connection and feedback existing in it /5/. An organic interrelationship of the indicated investigations is the objective basis on which the cooperation between labor hygiene and ergonomics appears and develops.

Ergonomics studies the effect of industrial environmental factors on the quality of occupational activity and thereby stimulates the elaboration of certain problems of labor hygiene. B. Metz, using noise standardization as an example, examines the problems that are in the center of attention of ergonomics during the elaboration of standards for industrial environmental indicators. The French scientist includes the following in them: the effect of various types of noise on the speed and accuracy of solution of intellectual problems; use of continuous tone noise to mask impulse noise; special languages of sound communication under noise conditions; modification of the perceptibility of speech by means of loud exclamations or amplifying devices; effect of temporary threshold shifts on speech and on the perceptibility of acoustic signals under noise conditions; planning acoustic signals with due regard for the acoustic characteristics of the environment /14/.

Ergonomics and labor intensity. The characteristic of labor to produce functional work stress in the body of the working man is called intensity. The term "work stress" is to generalize all the changes in the body arising pending and during labor activity /8/. The concept "work stress" includes a number of more specific definitions characterizing various stages in its development--getting into work and fatigue--as well as its different features in nervous-emotional, monotonous and hard physical or local labor and under the effect of noise, vibration or various other factors.

Exceeding the threshold of a harmful effect, all the factors become the causes of diseases. At the same time, their effects below the threshold of a harmful effect are also of significant interest for labor protection. Such effects can change the "level of health," if one can use such an expression, remaining within the limits of a physiological norm.

All the factors affecting man can be divided into two groups according to their biological significance. One group in a certain dose is useful or even necessary for man's health (and his progeny), while another is not needed at all in any dose. The first includes man's muscular and any other activity in the process of labor and the effect of meteorological conditions and illuminations and some others. The second group should include, for example, the effect of many chemical substances appearing as a result of the development of the chemical industry. Today it is not yet easy to qualify a number of industrial factors appearing with the development of technology in such a way owing to the shortage of scientific data on their effect on man.

For the factors of the first group it is possible to determine the optimum dose in which they contribute to an improvement in man's health and development. Over a certain range (more or less than the optimum) these factors as yet do not violate the norm, but no longer have a positive effect on man's state. Greater deviations in both directions impair health and can become the cause of a disease. The harmfulness of excessive loads has been known for a long time and is the reason for many labor protection measures--elimination of hard physical labor, control of cold diseases, improvement of industrial illumination and so forth. Data on the unfavorable effects of even very small doses of some factors on the health of working people, as a result of which hypokinesis, an excessive monotony of labor, an excessive "hot-house" microclimate on airtight production premises and so forth are created, have been accumulated during the last few decades.

The factors of the second group in doses below the threshold of a harmful effect do not interfere with the preservation of health and the work stress produced by them does not exceed the boundaries of a physiological norm. The concept of the optimum of work stress is formulated in the investigations of physiologists /9/. In an ergonomic description of the correspondence of the means and conditions of labor to man's functional capabilities and his activity the concept of functional comfort meets such an optimum /7/. Measures ensuring the optimum level of work stress are worked out with due regard for the range of the body's adaptive reactions (adaptation) and the range of man's capabilities for mastering labor activity (training and exercise).

The problem of criteria for the evaluation of hard and intense labor, whose solution is possible only with a system approach and on the basis of the achievements of hygiene, physiology, psychology of labor, economy of labor and other disciplines, reflects the need for an organic interrelationship between labor protection and ergonomics to the greatest extent. The ergonomic

approach is the condition necessary for the study of hard and intense labor manifested in the indicators of the functional state of the body formed under the effect of a physical, psychic or nervous-emotional load and industrial environmental factors.

The state and work fitness of working people are determined by a combined effect of physical, chemical, biological and psychophysiological factors. The development of criteria for the evaluation of a one-time effect of various factors constitutes a special task of interdisciplinary investigations of many scientific disciplines. The indicated trend in investigations is another sphere of an organic interaction of labor protection and ergonomics.

An organic relationship between labor protection and ergonomics is one of the manifestations of the outlined tendency, according to which an efficient solution of the problems of labor safety and labor hygiene is attained when they are solved as integral parts of the general set of measures for the optimization of labor activity and the conditions of its implementation. In this respect the resolution adopted by the International Labor Conference in 1974 is noteworthy. In particular, it stresses that an "improvement in the industrial environment should be considered a global problem, in which various factors affecting the physical and mental state of workers, such as the following, are interconnected:

"protection against unfavorable physical conditions and danger at work places and in the environment immediately surrounding work places (for example, heat, radiation, dust, substances polluting the atmosphere, noise, air pressure, vibration, dangerous mechanisms, chemical substances and explosives);

"adaptation of installations and production processes for the physical and mental capabilities of workers through the use of the principles of ergonomics;

"prevention of mental stress caused by the pace and monotony of work and improvement in the quality of labor through an improvement in working conditions, including the nature and content of work, and other problems pertaining to labor organization" (quoted according to /2/).

The ergonomic recommendations used in labor protection assume the form of a law, standard or another normative document, and also can be part of the specific engineering and organizational solutions during the development of new equipment and technology, or in the process of operation of equipment under conditions of existing production.

In the practical implementation of the multiplane and long-term program for the transition from safety techniques to safe equipment the cooperation between labor protection and ergonomics plays an important role, because "today it is no longer possible to design a new machine," the editorial of the journal OKHRANA TRUDA I SOTSIAL'NOYE STRAKHOVANIYE stresses, "without taking into consideration the requirements of ergonomics and the system of labor safety standards concerning a specific type of production" /6, 7/.

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ERGONOMICS

RESEARCH ON OPERATOR PERFORMANCE AT CONTROL DESKS WITH MATRIX, MULTISTEP AND ADDRESS INFORMATION INPUT

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/Article by L. F. Solov'yeva, graduate student at Moscow State University, Yu. A. Tyapchenko, engineer, Moscow, and D. M. Ramendik, psychologist, Moscow State University/

/Text/ The solution of the problem of developing compact control desks becomes more and more complicated as the complexity of mobile objects increases and the level of their automation rises. Some ways of developing hardware ensuring the solution of this problem are set forth in studies by many authors /1, 8-13/. Compact reflection hardware is built according to the principles of compression or step-by-step presentation of information at the same work space of a control desk. At the same time, the number of control organs is to be reduced, using a multifunctional keyboard or information input coders /1/.

Command-signal control desks of the "command-signal ruler" type /1, 12/ and of the "command-signal field" type /1, 3, 4/ are the simplest among the compact control desks. These are devices with a matrix choice of control objects, a spatially unified field of information reflection and command devices.

Nonobservance of the requirements of engineering psychology during the installation of the information field in command-information compression devices discredits them, despite the obvious technical and economic advantages of these types of devices. Therefore, devices of the "command-signal field" type are used less frequently than others. The authors of the presented article set for themselves the task of finding ways of further increasing the efficiency of control desks with a scanning information field compatible with control command compression devices.

The way of spatially dividing signal and command fields and finding unified types of displays and keyboards acceptable for practical conditions is one of such ways /8/. The possibility of spatially dividing the signal field

and keyboard was investigated by F. Ye. Temnikov and B. Panshin /8/. Information was presented by them on mnemocircuits, control objects were numbered and commands were fed by means of two decimal keyboard units.

Three methods of choosing control objects, that is, multistep, address and matrix methods, are compared in the presented article. The latter is examined in two forms: 1) combination of the keyboard and information panel; 2) their spatial separation.

Methods

An especially designed unit[1] making it possible to use all the three methods of choosing the same objects was used in this study. It consisted of three basic parts: operator's, experimenter's and recorder's control desks. Two panels--an information panel inclined at an angle of 65° and an executive panel inclined at an angle of 15°--formed the operator's control desk.

There were 18 signal displays on the front of the information panel of the operator's control desk, each of which contained 3X5 electroluminescent signaling devices. The display was arranged in two horizontal rows, each having nine blocks (fig. 1).

The view of the executive panel depended on the investigated method of choosing objects.

The experimenter's control desk made it possible to light any window at the operator's control desk. The task of the tested individual was to switch off the window. For this purpose he had to press all the buttons corresponding to the code of a specific window in the used information input system and the "off" button.

The following moments were recorded in the course of the experiment: lighting the window; pressing the last code button; pressing the "off" button.

A total of 30 people aged 20 to 25 participated in the investigation. After training every tested individual performed 50 assignments.

The time of performance of every assignment, of decision making and of a motor action was analyzed. The data obtained were averaged out and their reliability was checked according to Student's criterion.

Experimental Results

The multistep method of choosing objects. The hierarchy of rules in such a method of choice was determined on the basis of the results of the conducted investigation /3/ and represented a logical tree containing five tiers. The

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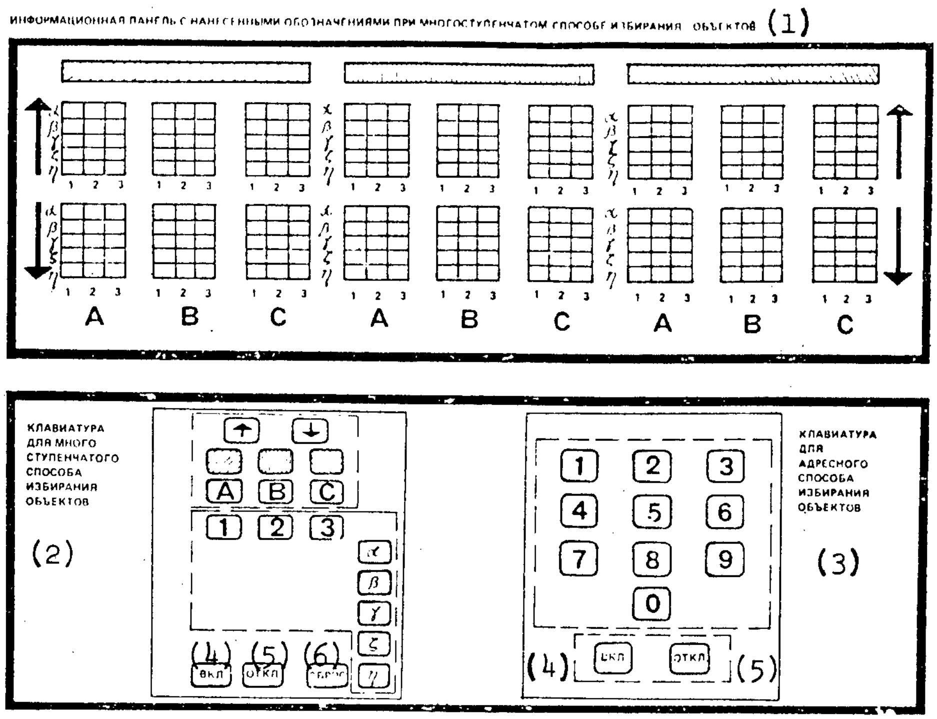
1. The experimental unit was developed with the participation of T. A. Vimer and M. M. Skakov.

first tier had two branches, the second, third and fourth, three branches each and the fifth tier (the last), five branches. Every object was characterized by five signs with a separate alphabet.



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1. Diagram of the Experimental Control Desk With an Address and Multistep Method of Choosing Objects

Key:
1. Information panel with plotted designations in the multistep method of choosing objects
2. Keyboard for the multistep method of choosing objects
3. Keyboard for the address method of choosing objects
4. On
5. Off
6. Clear

The alphabet of the first level contained two gradations, of the next three, three gradations each, and of the last sign, five gradations. Such a structure was carried out in this fashion. The following stood out in the information part of the control desk by means of special coloring and inscriptions: 1) the upper and lower rows of blocks; 2) six blocks (three upper and three lower) unified by color--blue, white or green; 3) in every color the pair of blocks arranged one under the other was designated by the letter A, B, or C; 4) in every block the columns consisting of five windows were numbered by figures 1, 2 and 3; 5) the windows forming part of one column were designated by the letters α, β, γ, ξ and η.

Thus, every window was characterized by five signs. There were 19 buttons on the executive panel, 16 of which corresponded to code signs (color, the position in the upper or lower half of the panel and so forth). "Off" and "clear" buttons had to be used in any method of choice.

In the multistep method of choosing objects the time of performance of the assignment T_3, that is, the time from feeding the signal to pressing the last button, was 6.8 seconds, on the average. Every tested individual made from one to five errors.

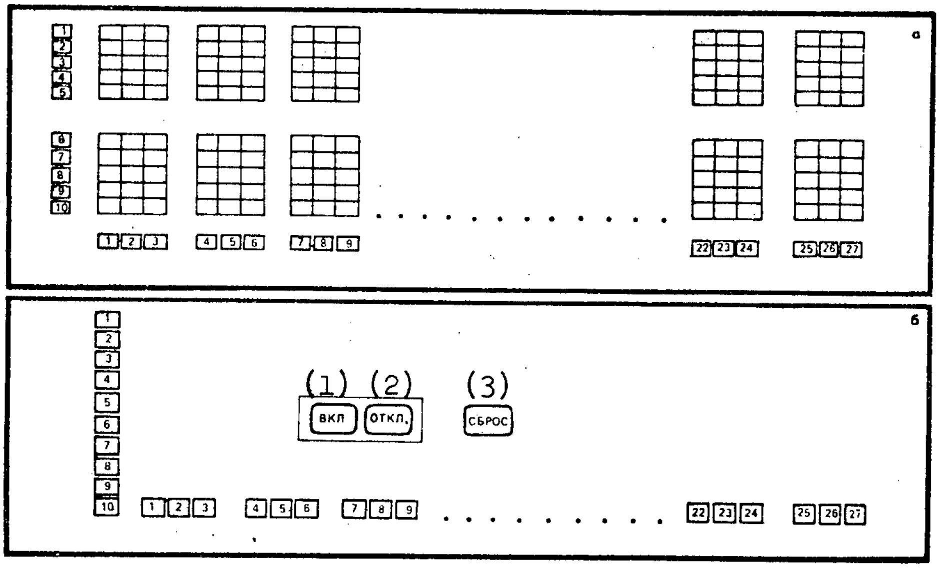
The time spent on motor components was defined as $t_{mk} = nt_1$, where n is the number of pressed buttons; t_1 is the time of pressing one button (the time from the moment of pressing the last code button to pressing the "off" button).

On the average, this magnitude was 0.5 seconds and statistically did not differ in all the ten tested individuals. Therefore, the motor action proper occupied $6t_1 = 3$ seconds, while decision making accounted for the remaining 3.8 seconds.

The address method of choosing objects. Ordinal numbers from 1 to 270 were entered in the windows of the information part. Only 10 out of the 14 code buttons of the executive part were used, the figure from 0 to 9 being written on each of them (see fig. 1). In the address method of choice the tested individuals performed the assignment in 1.9 seconds, on the average, and did not make errors.

The code of every window could contain one, two or three signs depending on how many figures the number of a window contained. Therefore, n--the number of signs and the number of buttons respectively--changed from one to three. When the number of signs in a code increased, the time of performance of the assignment T_3 was prolonged. The differences among the tested individuals were statistically insignificant and among the times for one, two and three signs, significant. In cases when a window had a simple number, it was switched off in 1.3 seconds, on the average. The increase in the number of a window caused an increase in the time of performance of the assignment by an average of 0.45 seconds per figure. The decision making time obtained by deducting the time of pressing buttons from the total time of performance of the assignment did not change when the number of signs in a window code increased, amounting to 0.7-0.8 seconds.

The matrix method of choosing objects. When the matrix method of choosing objects with a combined arrangement of the keyboard and information panel was investigated, two rows of buttons were attached directly to the information part (see the upper part of fig. 2). One row with 27 buttons was located directly under the windows (every button corresponded to one vertical row of windows) and the second, with 10 buttons, vertically, left to the windows (each of its buttons was opposite one horizontal row of windows, see fig. 2). In such a method of choice the assignment was performed without errors in 1.8 seconds, on the average.



2

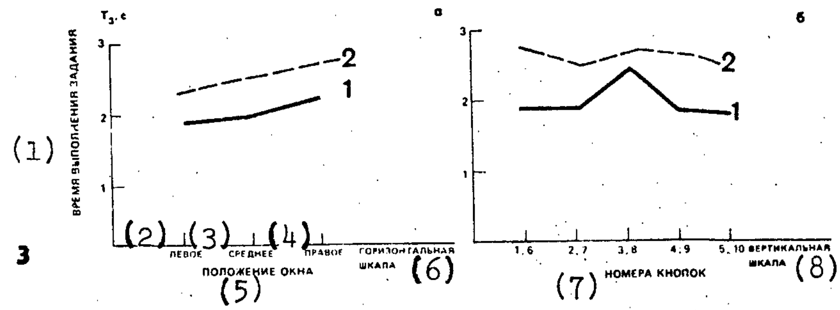
2. Diagram of the Experimental Control Desk With the Matrix Method of Choosing Objects:

a--panel of the control desk with the coordinate (matrix) method of choice,
б--executive part of the control desk with a keyboard spatially separate from the information field

Key:
1. On
2. Off
3. Clear

In the indicated arrangement of buttons the magnitude t_1 could not be calculated precisely, because the "off" button was on the executive panel and the distance to it from the working buttons depended on the location of the lighted window and of the button corresponding to it. However, similarly to the multistep and address methods of choice $t_1 = 0.5$ seconds, and since it was always necessary to press two buttons, the motor action occupied 1 second (in the matrix method the "off" button is not a working button). This time is slightly understated, because the period of hand movement is not taken into account. Accordingly, the decision making time equal to 0.8 seconds, on the average, is slightly overstated.

The effect of the motor component on the time of performance of the assignment was also disclosed by a slightly different method. The windows located along the horizontal scale in extremely right blocks (fig. 3a), on the average, are switched off 0.5 seconds more slowly than the rest (the differences are statistically significant).



3

3. Dependence of the Average Time of Performance of the Assignment on the Position of a Window (in the Matrix Method of Choosing Objects):

1--combined arrangement
2--spatial separation of the keyboard and information field

Key:

1. Time of performance of the assignment
2. Left
3. Mean
4. Right
5. Position of a window
6. Horizontal scale
7. Number of buttons
8. Vertical scale

Fig. 3б reflects the relationship between the average time of performance of the assignment and the position of a window along the vertical axis. The worst results were obtained for windows in rows three and eight located in the middle of the upper and lower halves of the information panel. For them the time of performance of the assignment was 0.5 seconds longer, on the average, than for the rest (the differences are statistically significant).

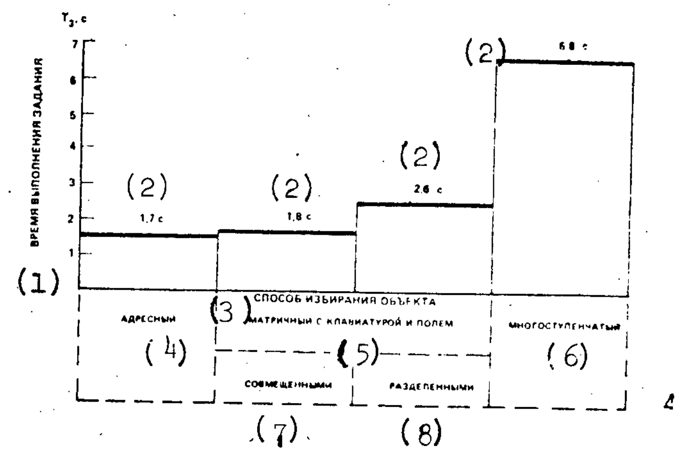
During a separate arrangement of the keyboard and information panel the rows of buttons identical to those used in a combined arrangement were placed on the executive part of the operator's control desk (see the lower part of fig. 2). The average time of performance of the assignment was 2.6 seconds, the time of the motor action, 1 second and decision making accounted for the rest.

On both graphs (see curves 2 in fig. 3) the differences among the points are statistically insignificant. In other words in this case the time of performance of the assignment does not depend on the position of a window.

The solution of the task set for the tested individuals included three basic stages: 1) finding the lighted window; 2) determining the code of this window and in accordance with this making a decision as to which buttons should

be pressed; 3) motor action--pressing the buttons. The first stage does not depend on the method of choice, because in all investigations the general view of the information panel does not change. The length of the third stage depends on the number of buttons that must be pressed and on the distance between these buttons.

The average time of performance of the assignment in all the three investigated methods of choice reaches the maximum in the multistep method (6.8 seconds). In the other methods of choice it ranges from 1.8 to 2.6 seconds (fig. 4).



4. Average Time of Performance of the Assignment in the Three Methods of Choosing an Object

Key:
1. Time of performance of the assignment
2. Seconds
3. Method of choosing an object
4. Address method
5. Matrix method with a keyboard and field
6. Multistep method
7. Combined
8. Separate

In the multistep method of choice the time of solving the task T_3 occupies more than one-half of the entire time of performance of the assignment (on the average, 3.8 seconds out of 6.8 seconds), which greatly exceeds the time of perception of a five-digit number /5/. This can be connected with the complexity of remembering five different signs that cannot be grouped /6, 7/.

In the address method of choice the decision making time does not depend on the number of signs in the number of a window, amounting to 0.7-0.8 seconds, which is equal to the time of perception of a three- or six-digit number /5/.

Since, on the average, the time of pressing one button is 0.5 seconds and the average number of uses of the address coder is equal to 1/2 for $K \geq 5$, where K is the number of digits of a number or the number of buttons /1/, the total time of performance of the assignment even for systems with a number of objects reaching tens of thousands will be 2.6 seconds.

In the matrix method of choice with a combined arrangement of the keyboard and information field the average time of performance of the assignment (1.8 seconds) is essentially equal to the corresponding values obtained in the address method of choice for windows with two-digit numbers (1.7 seconds). However, the efficiency of the indicated type of the matrix method of choice is lowered during operation with windows in the right end of the information panel or in the middle along the vertical axis (see fig. 3). This is due to the difficulty of moving a hand over a long distance, as well as to the complexity of correlating windows with the buttons corresponding to them. Therefore, it can be assumed that an increase in the number of objects both along the horizontal and vertical axis will lead to a reduction in the efficiency of the matrix method of choice with a combined arrangement of the keyboard and information field.

In the matrix method of choosing objects with a separate arrangement of the keyboard and information field the total time of performance of the assignment (on the average, 2.6 seconds) was significantly longer than in other methods of choice (the multistep method was an exception). The time increases mainly as a result of the increase in the decision making time, because the motor component remains almost unchanged--only two buttons are pressed. Such a change in the decision making time is connected with difficulties in the correlation of windows with the appropriate buttons, which in this case does not depend on the position of a window (see fig. 3). It should also be noted that in the separate arrangement the button lines were perpendicular to each other (similarly to the button lines in a combined arrangement). The tested individuals considered these buttons coordinates of the corresponding windows. It can be stated that, if both rows of buttons had been located in parallel, all these difficulties would have surfaced to an even greater extent.

In the multistep method of choice the tested individuals made errors, but their number did not exceed five, that is, 10 percent of the total number of presented assignments and, on the average, was 2.8 per tested individual. In the other methods of choice there were no errors, because the number of perceived parameters in all the methods of choice, apart from the multistep method, did not exceed three. Such a number of signs can be perceived directly and be easily retained in the short memory /6/. In the multistep method of choice the tested individual had to retain five different nongrouped parameters in his memory, which was close to the limit of the volume of the short memory /6, 7/. This could have been the source of the errors.

Thus, of all the examined command devices the address command device is the most efficient. Although under experimental conditions the matrix method of choice (with a combination of the keyboard and information field) is not

inferior to the address method, its efficiency depends on the number of control objects. The efficiency of multistep choice proved to be the lowest.

Conclusions and Recommendations

1. Of the two types of command-signal control desks with a matrix (coordinate) choice of control objects the command-signal field with an arrangement of the keyboard along the perpendicular sides of the signal field is preferable, because with a spatial separation of the field and keyboard it is advisable to place the button lines perpendicularly to each other, which leads to an inefficient use of the working field of the executive part of the control desk.

Analyzing the research results presented here and in the articles by B. F. Gul'ko et al. /4/, it can be assumed that the field measuring no more than 10X10 cells vertically and horizontally is the closest to the optimum.

2. In a random choice of control objects the efficiency of multistep control desks depends on the number of degrees of choosing control objects, that is, on the method of dividing the information field into parts. Two stages or the matrix method of choice is the limit of division. The efficiency of multistep control desks can be increased for problems sequentially solved by an operator. In this case, for example, the display is prechosen and then work is done within the information field of the chosen display.

3. The address method of coding, while in its efficiency not inferior to the coordinate (matrix) method, under practical conditions involves the need for coding all the cells of signal displays. This leads to a reduction in the field of the signaling device for recording sense inscriptions and is at variance with the requirements of engineering psychology and, when the size of the display are increased, with the requirements for compactness.

The division of a control problem into the following two parts is constructive: 1) choosing a display by the address method, 2) choosing a cell in the chosen display. It is desirable to have a display in which the choice of cells by means of an address device would present no difficulties for the operator, that is, a 3X3 display /1/. Such a display can be brought into correspondence with a keyboard block of the address device measuring 3X3 with their natural decimal numeration from left to right and from bottom to top /1/. At the same time, the address control desk should consist of two identical blocks of a decimal keyboard: a display choosing block (mnemocircuit, type of indication on a cathode ray tube and so forth) and a command feed block.

The address control desk with a decimal keyboard for choosing groups of objects and objects in the chosen group meets not only engineering psychological requirements, but also the requirements for the unification of displays,

control organs and the corresponding coding and decoding equipment. Such a control desk is not at variance with the trend in the development of control panels with the transition to display equipment and, therefore, can be recommended as the basic method of choosing objects at compact control desks.

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CSO: 1870

PSYCHIATRY

SERBSKIY DIRECTOR DISCUSSES COMPULSORY TREATMENT OF ALCOHOLICS

Moscow NEDELYA in Russian No 31, 1978 p 17

[Article by G. Morozov, Director of the Serbskiy Institute of Forensic Psychiatry]

[Text] Hardly anyone is indifferent to drunkeness, but doctors, who see the pernicious effects of this vice every day, are especially disturbed by it.

The condition of a person who has lost his reason under the influence of alcohol causes pain, anger, and anxiety. The fight against alcoholism has different aspects: economic, social, medical, and moral.

In contrast with many other illnesses, a predeliction for alcohol harms not only the drinker, but, to one degree or another, those living around him: his family, fellow workers and neighbors. An inclination to alcohol can be transmitted to the next generation and, certainly, has an effect on the health of children. It is the duty and responsibility of doctors to explain to the population the damage caused by drunkeness and--and this is no less important--to unmask and treat people liable to alcoholism in a timely manner.

Until recently narcological aid to those ill with chronic alcoholism was conducted within the structure of the country's psychiatric service. However, an analysis made by the Ministry of Health of the USSR revealed a number of defects in the organization of treatment. For example, those ill with alcoholism were registered for the most part only when they themselves sought narcological aid. Unfortunately, this does happen frequently. Ordinarily, such people, regardless of their education, cultural level, and position in the society, deny their inclination to alcoholism or understate its dimensions. As a result, these patients come to the narcological specialist late, with a severly aggravated form of the illness, and this cannot but have an impact on the effectiveness of the treatment. In this case, doctors use only some single method of treatment, without adequately

taking into consideration the individual characteristics of the patient and his illness. The micro-social conditions of the environment within which the patient's inclination to alcoholism was formed does not have much importance attached to it, while this question is at the same time one of the most important, and a great deal of attention must be paid to it when organizing the treatment of the patient. The doctor must determine and point out those changes in the patient's micro-environment that would help treatment. The family and the administration and social organizations of industry must help in this matter, depending on the doctor's recommendations. As you can see, a comprehensive approach is necessary in treating alcoholism.

A few years ago a method of treating alcoholism patients in narcological divisions, organized within industrial enterprises, at construction sites and in agricultural areas was proposed and approved for the first time, and this method has been highly praised. This new form of organizing treatment has unquestioned advantages over other methods of in-patient treatment. Its chief feature that makes it different is the combination of different methods of treatment with regular continued work by the patient in industry. The fact that the patient is paid for his work, but with sixty percent of the money paid sent to the family and forty percent going into the account of the narcological division, is of no small importance. These funds go to improving the living conditions and treatment of the patients.

Experience gained in reorganizing medical aid for alcoholism patients proves the correctness of reorganizing and improving the narcological service.

What is the narcological service at the present time and what are the features that make it different?

This is an interrelated system of in-patient and out-patient sub-divisions, differing in structure and character, located as close to the population as possible, and united under a single organizational-methodological center. Such a system permits embracing the entire contingent of alcoholism patients, regardless of the degree of illness and attitude of the patient himself. Moreover, the fact that the system that has been created works in close connection with all of the departments, organs and organizations concerned with the fight against drunkeness is a feature that makes it different.

Doctors specializing in narcology, social and industrial organizations, can work in close connection, unmasking those ill with alcoholism in time. Social narcological posts with the participation of collectives at enterprises and activists of the Red Cross and Red Crescent can do a great deal to facilitate this.

An independent narcological service will allow rendering aid to all persons, regardless of their attitude to their illness and desire to be treated. There are, unfortunately, two categories of alcoholism patients, and they

are sharply different from each other. The first category are those who recognize the necessity for treatment and understand the harm in abusing alcoholic beverages and the necessity of medical help. But for one or another reason, most frequently of a professional nature, they do not want publicity and do not turn to doctors at the in-patient or out-patient narcological service for help. However, if such people are not treated in time, their illness may progress and lead not only to professional failure, in which case their basic reason for avoiding treatment eliminates itself, but the effectiveness of subsequent treatment also will be decreased. For such patients, narcological offices at self-supporting polyclinics have been opened, at which anti-alcoholism treatment is carried out anonymously. The patient, without giving his name, pays for the course of treatment entirely and receives all the necessary types of therapy. Such a form of narcological aid is gaining more and more recognition among the population.

Unfortunately, there is also another category of people, who are rather numerous. These patients openly deny their inclination to drink and therefore completely avoid anti-alcoholic treatment. Naturally, in this case it is practically impossible to apply any sort of persuasion by a doctor or any sort of social influence. It is necessary to turn to the law on compulsory treatment. And for three years after release from a treatment institution these patients will be observed by doctors of the narcological service at their place of residence.

Drunkeness causes tears and unhappiness, and we must apply all our efforts to eliminate such a grave ailment from our society.

CSO: 1870

VETERINARY MEDICINE

UDC 637

BIOLOGICAL ASSESSMENT OF FEED AND FOOD PRODUCT PRODUCTION PROCEDURES

Moscow VESTNIK SEL'SKOKHOZYAYSTVENNOY NAUKI in Russian No 4, 1978 pp 74-86

[Article by VASKhNIL Academician N. G. Belen'kiy, Dr Med Sci A. D. Ignat'yev, and Dr Biol Sci V. Ya. Shabliy]

[Text] The concept of the quality of feed, agricultural raw materials, and food products is defined not only by many technical-economic factors of agricultural and food production but also the purely specific nature--the biological value--of feed (1-7) and food products. Biological value is the basis from which we determine whether or not feed would satisfy the physiological needs of animals with a consideration for optimum productivity, and food would satisfy man's nutritional needs in support of his vital activities. Biological value is characterized by an aggregate of integrated indices--harmlessness, nutritive value, biological activity, and organoleptic activity.

Harmlessness means absence of specific and nonspecific toxicity, as determined from the diverse indices of the body's vital activities (general condition, nutrition, growth, development, long life, metabolism, and functional activity of organs and systems, to include reproduction of progeny in several generations, as well as the same parameters of their vital activities). Some researchers interpret harmlessness, usually toxicity, as something apart from biological value, functioning in accordance with its own specific laws. However, we cannot agree with such a one-sided conception. It attaches dominating significance to presence (residues) of harmful substances, and not to the aggregate of the content and properties of the food or feed affecting the body as a whole. All manifestations of toxicity are the result of impairment of particular aspects of metabolism that simultaneously characterize nutrition. Harmful factors act directly or indirectly at the same level and with the participation of the same mechanisms responsible for the action of nutrients and their metabolites.

Unfortunately, maximum permissible quantities of harmful substances in feed and food products are still being set without a consideration for this integrity. And it is only in recent years that greater significance has been attached to feeding and nutrition as the most important and sometimes the decisive factors in development of intoxication or alimentary disease.

Nutritive value is a complex, diverse concept, close to the concept of "food value" but not identical to it. Food value describes feed or a food product as such on the basis of its chemical composition--that is, the quantity of substances and compounds participating in body building. They include proteins, fats, carbohydrates, vitamins, water, salts, macro- and microelements. Depending on the features of the structures they form, the same substances may or may not have nutritive properties and may even be harmful to the body. This is why food value, when it is not supplemented by considerations of nutritive value, has indefinite meaning, meaning which could be made concrete only through biological tests: We cannot assess the nutritive value of a new feed or food product only on the basis of its chemical analysis, without biological testing.

Energy value is rightfully included in the concept of "food value" as well, and it should not be isolated as a special property, as is done by some specialists. However, total energy value is determined not through biological tests but rather by combustion in calorometric bombs, as a result of which feed and food products differeing in nutritive value and true energy value may contain the same amount of total energy.

Thus nutritive value characterizes the body's ability to utilize nutrients and energy during consumption of feed or food and in metabolic pathways. Consumption of feed or food begins with relatively passive reactions by the body--perception of taste, aroma, and consistency, which are then superseded by active breakdown of the food substrate--its grinding and processing by digestive juices until it reaches a state suitable for assimilation. The feed or food is next actively transformed by the body; the assimilated substrate is transformed into body components and metabolites. Specific features of the body, upon which manifestation of properties imparted by nature to the feed or food product depend, have dominant significance in these processes. Thus while food value is an absolute concept characterizing the product as such, nutritive value is a relative concept defining the results of interaction between the food product and the body, constantly changing in response to not only nutritional but also other factors of the outer and inner environments.

Biological activity is the capability of feed or the food product to stimulate metabolic processes through the action of specific highly active substances or structures. For example, growth is activated by presence of nucleic acids (yeasts, meat) or protein peptides (so-called "animal protein factors") or biologically active radicals, enzymes, and so on in the food. This can be seen especially distinctly in the differences in biological value of the same food product when cooked and raw. As an example raw meat is significantly more active than is cooked meat.

Preliminary data from our experiments permit the hypothesis that the length of life of the test object is apparently the most meaningful index of "biological activity," integrating many of its indices.

Organoleptic value has to do with the sensation perceived from the feed or food consumed. It is the dominant factor of appetite, and it has biological significance to animals.

In relation to man, meanwhile, organoleptic assessment of a food is associated not only with its biological perception but also with social factors (habits, tastes, and so on), which makes such an assessment extremely relative, subjective.

All of this hinders establishment of standard criteria of biological value, and it generates a multiplicity of conceptions concerning the essence of the principles and methods of balanced animal feeding and sensible human nutrition, and practical implementation of these principles and methods.

Biological value is determined from the effect feed or food has on living test organisms; however, this does not at all preclude other assessment methods, including chemical and physical, assuming they are calibrated with sufficient adequacy in relation to the prescribed analysis parameters on the scale of the biological samples.

Chemical methods, which came into broad use in the middle of the last century to assess the quality of feed and food products, could be used to determine their composition and quantitatively measure their elementary components. Chromatography played a tremendous role in establishing elementary structures, especially of amino acids. It served as the foundation for evaluating the quality of foods of animal origin on the basis of not only total nitrogen content but also amino acid content. It was found that protein from the whole chicken egg is the most balanced in relation to this index (20). The set of its essential amino acids--the score--was adopted as the ideal standard of quality (100 percent). The set of essential amino acids in mother's milk and amino acid scales of "ideal" protein were later proposed as scores (FAO, 1965, 1970). Biological value is computed using such scores by comparing the percent content of amino acids in the foods under analysis with the scale of the standard protein. A number of formulas have been proposed for computing scores (Block, Oser, Korpachi, Pokrovskiy and others).* The scores were found to be inaccurate when it came to determining the human need for amino acids; they were replaced by others, but they never came into broad use inasmuch as it was found that scores do not correspond reliably to the results of biological testing.

*Formulas for computing scores are described in the pamphlets "Metodicheskiye rekomendatsii po biologicheskoy otsenke produktov pitaniya" (Methodological recommendations on biological assessment of food products), VASKhNIL, Moscow, 1973; "Metody biologicheskoy otsenki produktov zhyvotnovodstva" (Methods for biological assessment of animal husbandry products), VASKhNIL, Moscow, 1975.

Highly persuasive data revealing a discrepancy between assessments made on the basis of amino acid content and biological methods were obtained by colleagues of the All-Union Scientific Research Institute of Animal Husbandry who studied the biological value of meat from four groups of calves raised on a straw-concentrate ration enriched with different doses of urea. The quality of the meat, determined by computation from an amino acid analysis, was compared with biological assessments obtained with rats. As we can see from the table below, the best quality meat, as determined from chemical analysis and computed indices, was from animals (in order of diminishing quality) in groups XI, XII, V, and I, while diametrically opposite results were obtained with biological assessment. In order of diminishing quality, meat of the best quality was obtained from animals in groups V, I, XII, and XI. Consequently amino acid composition and biological value are not identical, and computations based on scores and other chemical indices do not reflect the biological qualities of a food product. More and more new indices are being introduced to assess food products. Thus meat is analyzed for protein, protein fractions, fats and fatty acids, total and bound moisture, ash and its components, amino acids including oxyproline and tryptophan, vitamins, color, tenderness, juiciness, marbling, muscle fiber diameter, and so on, for a total of more than 50 indices. An attentive examination would force the assertion that the quantity of protein in muscle tissues from animals of different species is relatively constant. Inflation of the proportion of protein occurs due to its mistaken identification in protein analyses, while a low quantity is a result of error in computations not accounting for the content of fat, which is the most variable in the chemical content of the meat of animals of "chemical maturity." It is believed, on the basis of the old, still persisting traditions of assessing meat on the basis of calorie content, that fat deposits in the carcass is a positive phenomenon. Meanwhile fat content or, as it is called, fatness, continues to serve as the criterion by which to differentiate carcass quality and place carcasses in different salability classes. The greater the fatness of the carcass, the higher is the purchase price. Only excessive carcass fatness is believed to be negative. But what do excessive and insufficient fatness mean; what are the objective criteria of this index? World animal husbandry practice has none yet, which results in subjective, approximate assessments. Examples have been reported of a 50 percent discrepancy in opinions concerning the quality of particular carcasses offered for individual assessment to a group of the most experienced experts.

The mistaken point of view is maintained that with age, the relative quantity of muscle tissue and, consequently, of protein in the animal body increases, and that the proportion of fat increases and moisture content declines simultaneously. In fact, however, the ratio of moisture to protein in the body remains stable throughout the productive period of the animals's life. The opinion exists that reducing the oxyproline content

Meat Quality (%) According to Chemical Analysis
Data and Biological Assessment Methods

(1) Способ биологической оценки	(2) Группы животных*			
	I	V	XI	XII
(3) По Митчеллу и Блоку	64,49	67,39	69,24	68,45
По Озеру (4)	66,68	68,94	70,13	68,54
(5) Стандарт ФАО, 1957	69,67	73,15	75,37	74,42
Стандарт ФАО, 1970 (6)	90,46	91,86	93,12	92,05
(7) По Митчеллу на крысах	87,4	98,2	79,2	82,3

Note: I--Control Group: Experimental ration--1.3-1.4 kg straw, 1 kg concentrates per 100 kg live weight, 25 kg greenery in summer or silage in fall-winter; V--Experimental ration and silage plus 200 gm urea; XI--Experimental ration and grass plus 200 gm urea; XII--Experimental ration and silage plus 400 gm urea.

Key:
1. Biological assessment method
2. Animal group*
3. Mitchell and Block
4. Oser
5. FAO standard, 1957
6. FAO standard, 1970
7. Mitchell, on rats

and increasing the tryptophan content have decisive significance to heightening the nutritive content of meat. If this is so, why, for example, is the nutritive content of blood, which contains almost no oxyproline, lower than that of meat, which contains significantly more oxyproline? Were we to turn to plant foods, we would find that there is even more oxyproline in cereal grains--up to 6 percent more with respect to protein, but this amino acid is not what limits their nutritive value.

That the significance of the tryptophan-oxyproline index is exaggerated can also be seen from the fact that excretion of oxyproline with urine increases among underdeveloped children, and this leads to an increase in the demand for it by the body. As a result meat having a higher collagen content is more nutritional for such children than is ordinary meat. This is yet another confirmation of the inadequacy of the biological grounds of this index of meat quality.

The decisive significance of chemical content (quantity of amino acids, polyunsaturated fatty acids, vitamins, minerals), which is placed at the basis of biological value computations (16,17), is also exaggerated. As has been proven by many authors, the quantity of amino acids is basically the same in meat from different species of animals taken from identical anatomical areas of the body (18,27). This is even confirmed by Japanese scientists, who have provided the most sophisticated amino acid analyzers

to the world. We note, however, that as compared to microbiological assessment methods, even these instruments, which are the most accurate ones available today, inflate the amino acid content by 20-30 percent (FAO, 1970); this problem is associated with the specific features of the chemical and chromatographic methods employed, which cannot be used to differentiate between l- and d- amino acids, differing in biological activity. In addition to the amino acid composition of proteins, peptide bonds between amino acids have decisive significance to manifestation of the biological properties of proteins. This is why an amino acid mixture imitating in composition a natural food or its hydrolysate is always less complete than the natural food itself. A similar law has been established through analysis of other nutrients. The fact that chemical composition and biological value are not identical is confirmed by good assimilation of alpha-sugars and poor assimilation of beta-sugars and cis-isomers of fatty acids, as compared to trans-isomers.

We know that minerals, vitamins, and polyunsaturated fatty acids occur in greater amounts in plants than in animal substrates and, consequently, this index does not adequately represent the latter as foods. However, despite the advantages these indices give to plant foods, in terms of biological value the latter are poorer than food of animal origin. In a sensible combination, however, they insure optimum nutrition and realization of the biological potential they embody. This pertains also to lipids, which increase the productivity of agricultural animals when added to their ration. Readily assimilated plant and animal fats are characterized by multifaceted biological action. Research by many scientists has demonstrated the effect of the lipid component of feed on the structure and function of cellular and subcellular membranes, with the state of which body metabolism as a whole is associated.

Attempts at introducing, as a means for assessing lipid quality, the coefficient of fatty acid metabolization effectiveness (KEM) deserves attention. This coefficient is the ratio of the concentration of arachidonic acid in mitochondria to the sum of all other polyunsaturated fatty acids containing 20 and 22 carbon atoms(16). The KEM has not as yet enjoyed practical application, since it is very difficult, expensive, and laborious to isolate mitochondria and their fractions. Moreover mitochondria are only one of many body structures, and they do not reflect vital activities in their entirety. It would be advisable to conduct further research and establish constants usable in broad practice, characterizing in integration the usefulness of lipids in determining biological value of raw materials and food products. In our opinion what we need here is the same sort of differentiated approach seen in the study of the biological effectiveness of protein substrates.

Assimilability and even digestibility of feeds and food products are associated more with physicochemical structure than with chemical composition. We cannot agree with the opinion that chemical composition and

structure of a food product are the same. Otherwise despite similarity in protein quantity and amino acid composition,how could we explain the differences, seen in relation to many indices, among different types of meat? Differences between chemical composition and structure have also been established for other food products. We have used meat as the example because its production is more expensive than all other foods.

The efficiency of meat animals is only 10-15 percent. Thus it is no accident that the trend seen today is to substitute food products mainly of animal and not of plant origin by synthetic substrates. The question as to the suitability of including up to 25 percent meat substitutes in the ration of every inhabitant in the next 10 years is being raised in a number of the world's countries.

This line, which has been labeled technical progress, is based on the notion that synthetic meat is a set of chemical compounds corresponding to the composition of the natural food product. But another index--moreover the one that is the most important--is ignored--structure. Meanwhile the chemical and biological properties of traditional and synthetic foods are far from identical, as is evidenced by numerous comparative biological assessments of synthetic and natural meat.

Meat is not a simple set of chemical elements; instead, it is a structural formation that is species-specific, to which the human body and the aspects of man's vital activities do not remain indifferent. The more pronounced the differences in metabolism of man and the animal producing meat are, the less the meat is biologically active, and vice versa. It is no accident that our research (N. G. Belen'kiy, A. I. Sokolova, 1955) revealed that feeding dog meat to dogs inhibits most of their physiological functions, including the sex function. In experiments conducted by other authors, addition of poultry fat to the ration of a bird reduced its vital activities, while enrichment of the ration by beef fat increased its vital activities. Feeding a Ciliate substrate to Ciliata dramatically entensifies their aging and die-off. These examples of the negative effect of foods characterized by high biological value upon the body are more than sufficient.

Use of nontraditional and, all the more so, other nonfood components to produce meat, milk, roe, and other articles with the goal of economizing on natural raw foods must be based mainly on the biological value of the end product, and not just on its chemical identity to the natural standards.

An order of succession exists in the nature of every food: Chemical composition-- physicochemical structure--biological value. The latter cannot be fully explained by either chemical composition, or "chemical scores," or the "food value formula." Biological value can be understood only through structures, the direct methods for determining which are practically

nonexistent at this time. This is why we are faced by the need for developing them immediately.

The discrepancy between chemical composition and biological value has encouraged scientists many times to search for a so-called "animal protein factor." As would have been expected, these attempts ended in failure each time. There is no such factor; instead, there are structures characterized by different degrees of complexity--protein-protein, protein-lipid, protein-lipid-carbohydrate, and so on. Apparently the properties of feed and food products depend mainly on the nature of these structures.

In experiments performed to determine biological value with Ciliata, it was noted in particular that they react more actively--that is, with greater biological results--to the peptide bonds of amino acids than to free amino acids.

It is precisely by differences in structure that we can explain the lower biological value of soluble, unstructured protein components in meat, fish, synthetic amino acids, and fatty acids. A quick method for biological assessment of milk using Ciliata as the test object reveals that there is no agreement between the absolute concentrations of proteins and fats and the biological value of milk. Consequently neither protein nor fat, taken separately, can be the absolute and decisive indices of milk quality, though such indices are being used today. We can say with full confidence that so-called "normalization" of milk has no correspondence with its normalization in relation to biological value defined by complexity of structure and not by the sum of its nutrients. A summary index of milk quality is unavailable, and an equivalent of it that has been found--biological value--has not as yet been introduced into the standards on milk mandatorily followed by farms and dairies.

Similar information indicating the discrepancy between chemical composition and biological value of feed and food products is accumulating abroad as well. The question arises: To what extent can even thorough study of the chemical composition of feeds and foods be used as the sole criterion for their assessment in agricultural production and of the procedures for processing raw food into finished products? From our point of view this question was answered correctly by the CEMA Commission for Coordination of Scientific Research on the Problem "Basic Directions of Scientific Research on Acquisition of High Quality Food Products on the Basis of the Scientific Achievements of Agriculture, Biology, Chemistry, Biochemistry, and Microbiology" (1971): It asserted that chemical information on meat quality "fails to adequately describe the biological value of the finished product obtained depending on the production procedures employed," and we should agree completely with this assertion. Chemical assessment is important and necessary, but it is passive, since it reflects only the potential of the food product as a source of nutrition. Biological value and an inherent part of it--biological efficiency of energy--provide information of greater significance.

Even less work has been done on the methodological approaches to determining the vitamin and mineral efficiency of feeds and food products: Little light has been shed on their interaction with enzymes and hormones in the body. We have not as yet determined whether we should assess them separately as such (but then this would not correspond to the real picture of feeding rations consisting of mixed components) or study them as part of the ration (but then because of the infinite diversity of ration composition, we would have to analyze and assess each ration separately, which would be unrealistic).

As a rule, biological methods used to determine biological quality are based on rations containing balanced quantities of nutrients and energy and different only in the quality of the dietary resources and components assessed.

Absolute biological usefulness of feed or a food product can be established directly only through experiments on animals and observations of human beings. Relative biological value, meanwhile, which quantitatively characterizes the qualitative differences in feeds and food products depending on the procedures used to acquire them, is determined with test objects (rats, chicks, Ciliata, fly larvae, more rarely dogs, guinea pigs, mice, microbes, caterpillars, hamsters).

The entire spectrum of the numerous indices of the vital activities of test organisms is used for biological assessment of dietary raw protein and feeds (10-13). Among these diverse indices, however, there are those which summarize (integrate) others, thus characterizing either individual types and aspects of metabolism and levels of structural organization, or different periods of an organism's vital activities.

Growth-weight and balance methods are used most often in today's world practice of biological assessment. Toxicity parameters are determined in research on harmlessness (7,11,14). The organoleptic method is used to assess the social importance of the finished product.

As with Thomas (28) who was the first to propose the term "biological value," Pokrovskiy (16) believed it applicable only to protein substrates, inasmuch as biological value basically relies only on indices of protein metabolism. But most dietary substrates contain, in addition to protein, other dietary and nondietary components which affect the body and make themselves known through its protein structures. Therefore, when we assess a product in relation to protein, we are at the same time assessing both the protein efficiency and the overall efficiency of the feed or food product, its biological value. Priority is attached in biological assessment of protein substrates to determination of the coefficients of metabolization of the protein component, especially of anabolic activity. Meanwhile biological value of nonprotein components is determined

indirectly--on the basis of the food's effect on metabolism of a standard protein introduced into a standard ration in standardized quantities.

There are a number of anabolization coefficients. Analysis of our own and published data would show that growth-weight indices of protein efficiency are the integrating indices of the biological value of a food product: The protein efficiency ratio (PER), net protein utilization (NPU), and biological value (BV) [Russian version--nitrogen retention coefficient, KRA]. These values account for body weight gain, which depends on the degree and nature of metabolization of the food product by the test object. This is why these parameters provide closely agreeing results in determinations of biological value. Other biological constants also have their own significance, and they can be used as necessary to acquire additional information.

The method for determining biological value of foods with growing animals, mainly young rats, since they model human nutritional processes relatively completely, has enjoyed the greatest application (4,5,10,11,13). Rats are used most often to determine the PER, which characterizes weight gain per unit protein intake. This method was developed by Osborne, Mendel, and Ferry in 1919 following lengthy and unsuccessful attempts at determining the biological value of food products by chemical analysis of their amino acid composition. The method for determining the PER with test animals became the basis for major research on biological assessment that cannot be performed on people. Rats are used to study relative and comparative biological value, rather than absolute biological value. When a standard or control food product having a known absolute biological value is employed, the obtained data can be multiplied by a conversion factor for the human body.

Relative biological value quantitatively characterizes qualitative differences of food products related by chemical composition but obtained through different production procedures, for example beef from animals fed various doses of urea, premixed rations, and biologically and chemically synthesized feeds. Comparative biological value can also be used to describe differences among foods of different kinds, bread and meat for example.

While relative biological value indicates weight loss or gain owing to change in food quality, comparative biological value reveals the amount of one food product needed to achieve the same biological impact of another food product. The ratio of bread to meat, for example, is 5:1. Standards such as chicken eggs, casein , amino acid mixtures, and others are used in research on comparative biological value.

An internal standard is used to compute relative biological value--the same product but produced in accordance with a control procedure. As an

Anabolization Indices

$$\text{FER (feed efficiency ratio)} = \frac{\text{weight gain}}{\text{feed intake}}$$

$$\text{PER (protein efficiency ratio)} = \frac{\text{weight gain}}{\text{protein intake}}$$

$$\text{ADR (apparent assimilability or digestibility ratio, \%)} = \frac{\text{intake nitrogen} - \text{fecal nitrogen}}{\text{intake nitrogen}} \cdot 100$$

$$\text{BV (biological value, \%)} = \frac{\text{intake nitrogen} - \text{fecal nitrogen} - \text{urinary nitrogen}}{\text{intake nitrogen} - \text{fecal nitrogen}} \cdot 100$$

$$\text{NPU (net protein utilization, \%)} = \frac{\text{intake nitrogen} - \text{fecal nitrogen} - \text{urinary nitrogen}}{\text{intake nitrogen}} \cdot 100$$

example casein cannot be used as an internal standard in meat analysis, as had been suggested by some nutrition specialists; this is true all the more so because it cannot be an absolute internal standard, since different forms of casein have different biological values. A standard protein efficiency (PER) equal to 2.5 has been adopted for casein ; this is the figure used as the basis for the so-called true PER.

Use of the PER is quite valuable in control of the procedures employed in food production operations; this is why it is the most widely accepted index of food biological value in the world, and in a number of countries (Canada, USA, Peru) it has been included in some quality standards (23). Of course there have been complaints concerning this index in connection with the fact that changes in its value do not always agree with nitrogen retention by the body (some of the weight gain can be caused by accumulation of water, fats, and the contents of the gastrointestinal tract).

There are many examples in which meat has dramatically stimulated growth in rats and, consequently, the PER, but strange as it may seem, nitrogen retention by the body was low while the concentration of fat in the liver and other organs was high. This might have been elicited by presence of incidental biologically active compounds in the meat, having been transferred from feed to the animal body and having altered the biological properties of the meat. However, we cannot agree completely with the assertion that absence of a direct proportional dependence between growth rate and the quality of the proteins analyzed is a shortcoming of the PER. The great amount of information accumulated in the world literature and our own experience argue that the PER is an extremely good growth-weight index reflecting the most important aspect of vital activities.

To describe protein metabolism, determination of the nitrogen balance in rats and chicks and computation, on its basis, of the nitrogen retention coefficient (KRA), which characterizes the proportion of digested nitrogen retained by the body, has been proposed. Mitchell (26) called this index "biological value" (BV), believing it basic to biological assessment of proteinaceous food products.

It should be emphasized, and this is extremely important, that there is a certain discrepancy between digestion and assimilation: A food might be poorly digested, but the digested amount is assimilated intensively, and vice versa. Digestion and assimilation are two different physiological processes. In our opinion we cannot believe assessment and, all the more so, standardization of nutrition on the basis of digested protein, a broad practice in animal husbandry, to be satisfactory. It would be more correct to standardize on the basis of assimilated protein or other nutritional component.

In an assessment of a food product such as meat, its digestibility does not have special significance, since it is high in all cases. According to our data it varies within 87-93 percent, being 90 percent on the average (N. G. Belen'kiy, V. Ya. Shabliy, 1968; A. D. Ignat'yev, 1973). The same pertains to milk and other foods.

Net protein utilization (NPU), which characterizes the percentage of protein in food that is assimilated, has greater significance. It most fully reveals the correspondence between the quality and quantity of proteinaceous foods, and it permits direct conversion of quantity to quality. For meat for example, the NPU values are 90 percent for pork, 80 percent for veal, 75 percent for beef, 70 percent for lamb, and 65 percent for rabbit. Given these NPU values, to achieve the same biological impact on the human body, as compared to pork (given identical fat content) an individual would have to eat 5-10 percent more veal, 10-15 percent more beef, 15-20 percent more lamb, and 20-25 percent more rabbit. Consequently production of this meat would have to be increased by the same proportion. This is why the need arises for developing integrated indices as a measure of correspondence between quality and quantity. We suggest the concept of "biological potential" for this purpose.

The latter is defined as the quantity produced (CP) of a food having a given biological value (BV) in relation to a conditional product for which assimilation is adopted as 100 percent. As a result the "biological potential" of a food product is defined by the formula

$$BP = \frac{CP \cdot BV}{100} \text{ kg nominal product (NP) with 100\% assimilation.}$$

The "biological potential" can also be achieved by a rise in the quantitative indices of production or of another product, and by improvement of its

quality. Here are some examples of computing biological potential. Thus assume that 100 kg of a food product with a biological value of 50 percent was produced by process A and the same amount (100 kg) of a product having greater biological value--70 percent--was produced by process B. As a result:

$$BP(A) = \frac{100 \cdot 50}{100} = 50 \text{ kg NP}, \quad BP(B) = \frac{100 \cdot 70}{100} = 70 \text{ kg NP}.$$

In another case assume that a food product of identical biological value--60 percent--was produced, 50 kg by process A and 70 kg by process B. Then BP(A) would be equal to 30 kg NP, while BP(B) would be 42 kg NP. In both cases process B is 40 percent more productive than process A.

Here is another example. Two protein concentrates have been produced--A with a protein content of 60 percent and a biological value of 40 percent, and B with a protein content of 40 percent and a biological value of 60 percent. Which of the two food products has a greater nutritional value? We find that both are the same, since both BP(A) and BP(B) equal 24 percent in relation to nominal protein with a biological value of 100 percent.

In summary, as we can see from both examples the cost of production itself is the criterion by which we decide whether to produce the food product by process A or process B; this closes the triangle upon which social production is based--quantity, quality, cost.

The "biological potential" category opens new perspectives for producing feeds and food products, since it allows us to commensurate quality with quanitity and elevate quality into an objective economic category through quantity. Moreover biological potential also permits us to compute the biological effectiveness of production processes. The latter is defined as the percent ratio of the biological potential of a finished food product (or raw food) to the biological potential of the expended raw food or feed. According to our data not less than 20 percent of the initial meat is lost in the processing of raw materials of animal origin into meat products. Apparently the percent lost is even higher when we process milk into dairy products. This is why it would make sense to review, using biological assessment as our control, many production operations in animal husbandry, plant growing, and dairy and food processing industry with the goal of heightening the biological potential of raw food and finished products. In this connection it is now becoming necessary to review, in the near future, the adopted norms of public demand for meat, milk, and other foods and develop new, more economical, physiologically grounded norms with a consideration for improvement of their biological potential in the Tenth Five-Year Plan.

Using the biological potential of food products, we must develop the procedures for producing an assortment of articles satisfying public

demand not only in different zones of the country but also in relation to age and occupation, and food products intended for preventive and therapeutic purposes. For this purpose, however, we would need to differentiate the most representative indices of biological value further and improve their scientific grounds.

While the procedures of biological assessment are more or less developed for cereals, pulse crops, meat, meat products, and fish and can be used for practical purposes, we have never had a method by which to make a biological assessment of milk, since experimenters have not been able to find a suitable test object for this purpose (recall that it should be a growing organism). It is entirely obvious that a child cannot serve as a test object. Nor can rats be used, since in biological assessment experiments with milk they die due to lack of protein in the milk ration (3.2 percent, while a minimum of 5-6 percent is needed). The milk cannot be condensed, since it would then be a different product. This is why the biological value of uncondensed milk is identified with its chemical composition which, as we have demonstrated earlier, does not reflect true biological value. We were the first to suggest use of the Ciliate *Tetrahymena pyriformis** as the test object for biological assessment of milk to overcome these difficulties.

A large number of experiments have demonstrated the possibility for using this method for biological assessment of the overwhelming majority of proteinaceous foods--meat, milk, animal feeds and synthetic feeds, seafood, ready-to-eat foods, plant substrates, yeasts, bacterial biomass, microscopic algae, nonspecific protein sources, and so on. It has been established that as is the case with rats, use of Ciliates produces the most accurate, comparable results and prevents error only if we establish a particular titer--that is, that quantity of protein placed into reaction which would promote the relatively greatest growth of microorganisms at lowest protein expenditure. As a result, on the basis of different titers promoting identical growth of the test object, our judgment as to the quality of protein broadens and deepens, and the number or errors decreases. The recommended amount of protein for experiments with Ciliates--0.3 mg with respect to nitrogen, per 1 ml of medium, with insignificant corrections--is entirely acceptable for most foods. However, this quantity differs significantly for some proteins of animal and plant origin. The not entirely satisfactory results of using this method in work with some food products and feeds can apparently be explained precisely by understatement of this factor. Researchers must be cautioned to comply strictly with the procedural conditions of the microbiological method (the prescribed amount of nitrogen, presence of all components in the medium,

*"Metodicheskiye rekomendatsii po biologicheskoy otsenke produktov zhivotnovodstva i kormov s ispol'zovaniyem test-organizma tetrakhimena piriformis," (Methodological recommendations on biological assessment of animal husbandry products and feeds using *Tetrahymena pyriformis* as the test organism), VASKhNIL, Moscow, 1977.

optimum sterility, and so on). When this method is used to determine biological value, as is the case in experiments on higher animals (N. G. Belen'kiy, A. D. Ignat'yev, V. Ya. Shabliy, and others) we must strictly adhere to standardized conditions for the experiments, guaranteeing acquisition of authentic results maximally close to true.

A quick biological assessment method we are developing using fly larvae as the test object is extremely enticing (A. D. Ignat'yev, N. M. Pasechnik). It essentially entails determination of the weight of larvae, developing to the pupa stage, applied to a suspension of the food under analysis in an agar medium. The quantity of feed consumed by larvae over a particular period of ther life and some anabolic indices are determined as well. The sum total of the obtained data describes the relative biological value of the analyzed substrate.

However, quick biological assessment methods require further work, elaboration, and comparison with commonly accepted methods.

Thus at the present level of our knowledge we must limit ourselves for the time being to the metabolic constants of the living organism listed above, turning special attention to some general biological indices adequately reflecting the relative biological value of the substrate.

Accumulation of methodological materials will permit us to establish the most meaningful integral indices of the quality of feed or food having general biological significance to different animal organisms. Nevertheless we already have sufficiently persuasive information indicating the suitability of introducing the methods and principles of biological assessment into practice. Success will depend on unification of the complex of techniques for studying the biological value of food products.

VASKhNIL Department of Animal Husbandry and Veterinary Medicine has done much in this regard. It has published the "Metodicheskiye rekomendatsii po biologicheskoy otsenke produktov pitaniya " (Methodological recommendations on biological assessment of food products) (VASKhNIL, Moscow, 1973); it has published the collection "Metody biologicheskoy otsenki produktov zhivotnogo proiskhozhdeniya," (Methods for biological assessment of food products of animal origin) (VASKhNIL, Moscow, 1975) for broad discussion; it has published "Metodicheskiye rekomendatsii po opredeleniyu biologicheskoy tsennosti produktov zhivotnogo proiskhozhdeniya," (Methodological recommendations for determining the biological value of food products of animal origin) (VASKhNIL, Moscow, 1976) and "Metodicheskiye rekomendatsii po biologicheskoy otsenke produktov zhivotnovodstva i kormov s ispol'zovaniyem test-organizma tetrakhimena piriformis," (VASKhNIL, Moscow, 1977).

Now we must select, as being the most suitable for unification, analysis methods producing reliable, comparable data and officially approve and offer them for broad use at various levels--from institutes to production

laboratories monitoring the quality of feeds and food products. It is only on this condition that we can be sure that biological assessment will become an inseparable link in the chain of measures guaranteeing an increase in production of high quality of feeds and food products.

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